Control-oriented model of a dwelling coupled to a water-to-water heat pump system

R. Lepore, S. Nourricier, F. Renard, H. Diricq, M.-E. Duprez, E. Dumont, C. Renotte, V. Feldheim, M. Frère
Pole Energie, Faculté Polytechnique de Mons, Belgium
renato.lepore@fpms.ac.be

1 Introduction

The consumption of primary energy (mainly from fossil origin) has two major drawbacks: first, its increasing cost and scarcity, second, the production of undesirable carbon dioxide. As the domestic and tertiary sectors are responsible for around $30\ \%$ of the total primary energy consumption, reducing this consumption in buildings is nowadays of major concern (note the appearance of more severe standards concerning insulation and energy savings). To achieve these goals, various sources of renewable energy (solar, wind, biomass, geothermy,...) can be exploited. Among several techniques, heat pumps use the refrigeration thermodynamic cycle to extract heat from a colder outside air/ground and deliver it to the house, at higher temperature. This operation can be advantageously performed a priori at any time (in contrast with solar or wind energy). A description of this technique and its utilization is summarized in [1].
In this work, as depicted in figure 1, we consider a real one-family house, which uses a water-to-water heat pump as a heating system (Leuze, Belgium). The heat pump cold source and hot sink are the outside ambiance and a radiant floor, respectively.

2 Contribution and results

We adopt a reduced-order modelling as well as a unique programming language, namely Matlab®. This way, we intend to alleviate interfacing problems which arise when mixing different softwares and to better address model-based control in later stages of the study (e.g., if estimation-adaptation of time-varying parameters is required):

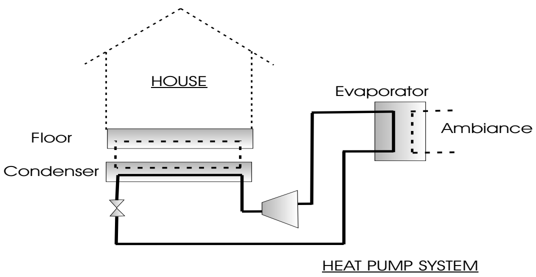

Figure 1: Principle of a dwelling coupled to the heat pump system using air as cold source.

- The house model is of the one-zone type and is based on a standard method describing the temperature nodes and the related heat fluxes. A small number of layers describes the walls and the floor (maximum three layers), all radiation and convection phenomena are lumped into global coefficients. This results into a set of nine Ordinary Differential Equations (ODEs).
- The heat pump is described by a set of Algebraic Equations (AEs), which is in agreement due to its high dynamics. The thermal phenomena in the heat exchangers (evaporator and condenser) are expressed using global transmission coefficients. The fluid properties and the calculation of the thermodynamic cycle are achieved using the NIST Refprop7® property database and the related access libraries.
- The radiant floor is described according to a one-dimensional model of piped thermo-active elements.

The model is validated in two ways:

- first, against a previously-developed model containing accurate descriptions of the house (Trnsys Type56® model) and of the heat pump;
- second, against the experimental data collected for several months, which are related to the house thermal phenomena as well as to the heat pump behaviour.

If model-based control strategies are to be addressed, computational performance is a nonnegligible aspect. In this case, it is noted that a great computational burden is due to the nested sets of algebraic equations to solve (in fact, REFPROP7 functions solve AEs). The computational performance decreases particularly when mixtures are used as fluids, as is often the case. The problem of accelerating this calculation step is also particularly addressed.

References

[1] Natural Resources Canada's Office of Energy Efficiency (EnerGuide team). (2004). Heating and cooling with a heat pump, see http://oee.nrcan.gc.ca/publications/.